Keysight Technologies
How to Test USB Type-C™ Alt Mode and the Standards Running Across It
Keysight and Type-C: Create a faster path to done
Overview

USB Type-C™ is a breakthrough standard designed to meet the demand for technology that supports new, ever smaller and thinner computers and devices, higher-speed data, and more power and flexibility. Key USB Type-C areas of focus include the connection between devices, managing power, and ensuring valid data transmissions. The USB Type-C connection provides:

- Dynamic power and transmission of USB 2.0 with other protocols
- The ability to be a key interface for many new and future devices
- Backward compatibility
- Ease-of-use as a result of reversibility

Design and test engineers face a number of challenges as they work to integrate USB Type-C into their products, while ensuring interoperability and achieving test compliance. Because USB Type-C compliance test standards have increased and become more complex due to higher data transmission speeds, more power, and additional functionality, successful testing requires highly accurate and standard-compliant test instruments, software, and fixtures.

This measurement brief is one in a series of five covering various aspects of the challenges and solutions for USB Type-C design and test. Topics covered in the series include:

- Cable and connector
- Power delivery
- Transmit/receive
- Simulation/measurement correlation
- Alternate (ALT) mode (DisplayPort, Thunderbolt, MHL)

Figure 1. USB Type-C pin out. Notice the symmetrical and reversible structure.
Type-C Alternate (Alt) Mode

The innovative USB Type-C connector and its new capabilities have captured the attention of other protocol standards organizations. Thunderbolt, DisplayPort (DP), and Mobile High-Definition Link (MHL) will use USB Type-C as their next generation interface connection. USB Type-C support of alternate protocols is made possible through the use of power delivery and Alternate (Alt) mode. The Alt mode enables USB Type-C to transmit and receive other protocols along with (or instead of) USB data and simultaneously provides USB 2.0 data transmission, and higher bi-directional charging capability for support of a wider range of devices. Alt mode works with the power delivery circuitry to transmit and receive unique data signals and more power, so the Type-C connection can also be used for many, non-USB, device connections and control. This measurement brief will focus predominantly on DisplayPort as an example application of Alt mode and its associated challenges and solutions.

How Alt Mode Works

After the initial end-to-end USB Type-C connection is established, cable orientation is detected and provider/consumer roles are acknowledged by the device, the USB Type-C power delivery circuit begins to negotiate and manage power for all connected devices. Power delivery negotiation allows devices to specify the power required and request adjustments to that power when needed for different functions. During the negotiation and discovery process, a device can request use of the Alt mode for its unique protocol requirements. The non-USB data is transmitted by repurposing pins in the USB Type-C cable for alternate data protocols.

The Type-C connection has four data lanes across eight pins, (TX1±, RX1±, TX2±, RX2±) and these lanes are capable of carrying USB 3.1, DisplayPort signals, or any alternate data protocol. The four high-speed Tx/Rx lanes, two sideband pins (SBU1 & SBU2), and either CC1 or CC2 are available for use during Alt mode transmissions. The D± pins are always reserved for USB 2.0 data transmissions, and the unused CC1/CC2 pin provides power to the active cable. The alternate protocol modes are configured by the power delivery circuit using voltage level messages through the connected configuration channel (CC1/CC2). Alt mode is very flexible and allows devices to dynamically reassign USB Type-C pin functionality by communicating with the power delivery CC1/CC2 channel. For example, a device could start-up as USB 3.1, then switch to DisplayPort 1.3.

In Alt mode, the SBU lines become active. The table below shows SBU line function for the different Alt mode technologies.

<table>
<thead>
<tr>
<th>Alt mode technology</th>
<th>SBU line function</th>
</tr>
</thead>
<tbody>
<tr>
<td>DisplayPort</td>
<td>AUX ±</td>
</tr>
<tr>
<td>MHL</td>
<td>e-CBUS-1, e-CBUS-2 (link discovery, management, clock)</td>
</tr>
<tr>
<td>Thunderbolt</td>
<td>Low-speed Rx and Tx lines (LSRX, LSTX)</td>
</tr>
</tbody>
</table>

Enabling USB alternate protocols to work with the USB Type-C connection has simplified device interconnection for consumers. However, designing, integrating and validating devices with the alternate protocols, USB data transfers, and dynamic power will require extensive characterization and a more intense compliance regimen.
USB Type-C Alt Mode Test Challenges

The amount of testing required during design and verification of USB Type-C devices using the alternate protocol is much greater than for USB Type-C conformance testing alone.

Key Alt mode test challenges:

- **Test and verification of the power delivery CC1/CC2 line to discover and configure Alt mode protocol - DisplayPort example:**
  The DisplayPort AUX lines are connected to SBU1/2 and the hot plug detect is added to the power delivery’s CC1/CC2 line as a packet, where it is converted to a command. The inability to easily change the content of the hot plug detect packet makes it difficult to perform any automated commands to simulate and verify the typical DisplayPort setup. The information passed to the power delivery CC1/CC2 line must be controlled for this type of testing.

- **Test Alt mode specifications**
  In addition to the USB Type-C specification, test specifications for the specific alternate protocol, such as DisplayPort, MHL, or Thunderbolt must also be verified. For Alt mode, there are specific areas, such as initialization and control, where testing can be especially challenging because various states of initialization, transmission, power level and other dynamic parameters require testing under many different scenarios. For example, the DisplayPort specification includes test requirements for various configurations of patterns, test points, levels and pre-emphasis.

- **Test Alt mode cable assemblies - DisplayPort example:**
  There are a number of challenges that are specific to the process of integrating DisplayPort over USB Type-C into your products, while ensuring interoperability and achieving test compliance. To ensure correct measurements, the different impedances of USB Type-C (85 Ω) and DisplayPort (100 Ω) need to be managed. In addition, a new signaling rate was added in the DisplayPort 1.3 specification, which increased the maximum bit rate to 8.1 Gbps/lane. This is a 50% increase in data rate resulting in a higher impact of loss, reflection, and crosstalk in your measurements. To ensure that the measurement is not affected by the test environment (such as test fixtures), a more rigorous approach to removing fixture effects is required.

To achieve successful USB Type-C and Alt mode test results in a timely manner, engineers will need the help of specialized instruments, software and solutions.
Keysight Solutions

The combination of USB and Alt mode capability with USB Type-C has multiplied the number of verification and conformance tests needed. Test development can be an overwhelming task for engineers that are not equipped with the instruments, fixtures, and software needed for Type-C devices, especially as the standards continue to evolve. Using products and solutions that are specifically designed for these challenging tasks can save time and expense and ensure reliable results.

Verification & Test of DisplayPort transmissions with a USB Type-C connector

The Keysight solution for test and verification of DisplayPort transmissions uses a reference sync, N7015A and N7016A fixtures, and a power delivery controller. The configuration enables communication to the device first via DisplayPort protocol and then converts to Type-C. The device under test can be controlled by setting the bit rates, level pre-emphasis and more. The test includes setting the AUX channel control for all the various DisplayPort modes and conditions.

Figure 3. Keysight solution for testing Alt mode (DisplayPort) transmissions.
Transmitter test solution

Keysight’s recommended test solution for DisplayPort Tx verification includes the use of a DSO V-Series Infiniium real-time oscilloscope, the U7232D DisplayPort compliance test software, and N7015A/N7016A TPA fixtures (Figure 3). The solution provides the ability to perform mathematical processing on the device’s transmitted signal, de-embed the fixture, and embed the cable (Figure 4). It enables continuous time linear equalization (CTLE) according to the desired specification and a decision feedback equalizer (DFE) applied to the highest bit rate. This solution supports acquiring the DisplayPort measurements required for the various configurations of patterns, test points, levels and pre-emphasis. The flexible software allows you to change parameter values in debug mode. Once the test is defined, it is able to cycle through the various scenarios automatically.

- Keysight DSA V-Series Infiniium oscilloscope
  - > 16 GHz with equalization
  - Jitter and de-embedding software used for eye diagram and jitter measurements

- U7232D DisplayPort 1.3 Compliance and Validation Test Software
  - Software guides the user sequentially through the tasks, ensuring minimal setup error, executes the tests specified by the DisplayPort 1.3 compliance test specification, and conveys the test information through a convenient software-generated report. Tests for inrush current and AUX channel PHY layer testing are also included.

- Type-C N7015A and N7016A test fixtures for test point adapters (Figure 5)
  - The N7015A Type-C high-speed test fixture (used with Infiniium oscilloscopes) offers the best signal integrity, with 20 GHz bandwidth (at -3 dB), and provides up to 30 GHz of de-embeddable bandwidth, enabling signal verification and debug of USB 3.1 10 Gbps, DisplayPort 1.3, and Thunderbolt 3 to support the Type-C connector. The fixture enables signal accessibility and probing to the device and host (upstream and downstream) ports. This is useful for access to all four Tx/Rx pairs, as well as the SBU signals for Alt mode.
  - The N7016A Type-C low-speed signal access and control fixture manages power and control lines from the N7015A Type-C high-speed test fixture to support termination requirements, test configuration, and connection to a power delivery controller. This fixture is especially helpful for debugging the power delivery protocol, offering signal access and characterization.
  - The N7016A connects to the N7015A Type-C high-speed test fixture providing access to USB 3.1 signals such as CC1, CC2, VBUS, SBU1, SBU2, and ground for system control and diagnosis. It can simultaneously flip the connection electronically (change the active USB 3.1 high-speed port) and break out VBUS for driving with a power controller or external supply. It can also load VCONN to simulate a system environment.

Figure 4. Keysight’s DP transmitter test solution provides the ability to perform mathematical processing on the device’s transmitted signal, de-embed the fixture, and embed the cable.
Receiver test solution

The Keysight test solution for DisplayPort receiver testing includes:

- Keysight M8020A high-performance serial J-BERT for level control, jitter addition, crosstalk addition, and calibration.
- N5990A automated compliance and device characterization test software for serial and multilane gigabit testing.
- A test sequencer and required instrument controls are included.
- The Keysight partner BitifEye Digital Test Solutions specializes in test automation and provides customizations and integrated solutions based on the N5990A Rx compliance software and the Keysight instrument portfolio.

Keysight solution for ALT mode (DisplayPort) cable assembly measurements

Managing the different impedance environments

The first challenge is managing the different impedance environments of 85 Ω for USB Type-C and 100 Ω for DisplayPort. Measurement and calibration in a non-50 Ω environment may be difficult or untraceable. Therefore, measurement and calibration should be done in a 50 Ω environment (using conventional calibration kits and techniques) and the results should then be re-normalized to the desired impedance. The port reference impedance conversion function of the E5071C ENA Option TDR can be used to re-normalize the USB Type-C port to 85 Ω.

Removing Fixture Effects from Measurement

Test fixtures are required in order to connect the test equipment to the cable assembly. At the 8.1 Gbps data rate, it is essential to remove the effects of the fixture to ensure sufficient yield. The “2x thru de-embedding” method is recommended. For 2x thru de-embedding, full calibration is performed with an electronic calibration (Ecal) unit to establish the calibration reference plane at the end of the test cables. Then, the S-parameters of the fixture traces are de-embedded to extend the reference plane to the edge of the USB connectors, effectively removing the effects of the fixture from the measurement. The key to the de-embedding method is the quality of the S-parameters of the fixture traces. The Automatic Fixture Removal (AFR) feature is recommended to obtain these S-parameters. The AFR function is available in Keysight’s N1930B Physical Layer Test System (PLTS) software. It provides a simple three step procedure to obtain highly accurate S-parameters of the fixtures.
Conclusion

The compliance tests for USB Type-C Alternate mode demand many more test regimens for each device. Using the best instruments, fixtures, and software available can help you address the increased number of tests, while making test setup easier, providing accurate signal generation and measurements, and automating tests when possible for repeatable results and reduced overall test times.

Keysight’s Type-C solution set—software, instruments and fixtures—is ready for complete testing of the standards converging on this universal interface. Whether you’re focused on design or validation, our solution will accelerate you from debug to characterization to compliance to done.

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